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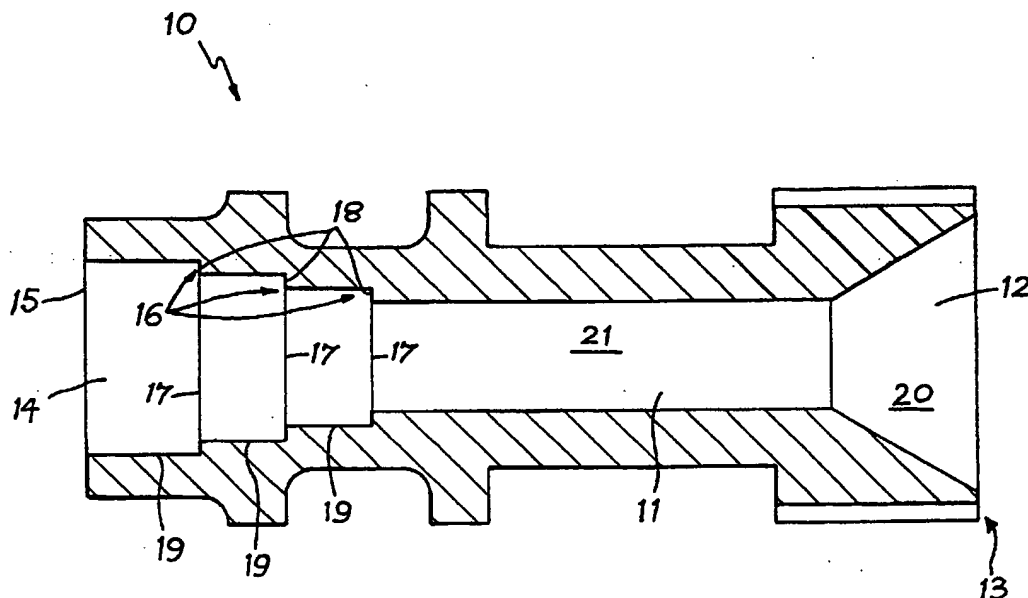
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(54) Title: NOZZLE FOR DELIVERING LIQUID/GAS MIXTURE



(57) Abstract

An expansion nozzle (10) for delivering liquid/gas mixtures comprises discontinuities (17) in the expansion section (14) toward the nozzle outlet (15). Those discontinuities (17) in the expansion section (14) function to ameliorate liquid film adherence at the nozzle outlet (15).

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NOZZLE FOR DELIVERING LIQUID/GAS MIXTURE**Technical Field**

5 The present invention relates to a nozzle for delivering a liquid/gas mixture to, for example, the intake manifold or combustion chamber of an internal combustion engine. The nozzle may form part of a fuel injector for an engine, particularly but not exclusively where the injector produces a mixture where a fine mist of fuel droplets are entrained in an airstream prior to being input to a combustion chamber.

10 Even though the present invention will be described in relation to a preferred application in fuel injectors for internal combustion engines it will be appreciated that it has applicability to any environment where a liquid droplet/gas mixture is to be delivered such that liquid film adherence at a nozzle outlet is to be ameliorated either in continuous or discontinuous delivery systems.

15 **Background Art**

It is known to create a liquid/gas mixture by delivering a generally cohesive sheet of liquid into a stream of gas flowing through a passage, with the gas acting to shear liquid droplets away from the sheet of liquid. Such a liquid/gas mixture has been found to have a significantly smaller average liquid droplet size than that produced by delivering liquid under pressure through a restricted nozzle to form a spray as many commonly available motor vehicle injectors operate. A liquid/gas mixing apparatus which operates by shearing liquid droplets away from a sheet of liquid is disclosed in AU-A-51454/93 and which is incorporated herein by reference.

20 Due to the very small size of the liquid droplets, the liquid/gas mixture produced by shearing liquid droplets from a sheet of liquid using a stream of gas can be delivered along a passage beyond the point at which the liquid is sheared from the sheet, and out through a nozzle.

25 If a nozzle has a simple continuous expansion zone leading to its outlet, it has been found that such a nozzle delivering liquid/gas mixtures tends to adhere liquid to and build up liquid on the inside surface of the expansion zone, and which liquid is pushed along the passage and out from the outlet as relatively large droplets as compared with the fine mist entrained in the stream of gas flowing into the nozzle.

30 It would be desirable to eliminate or at least minimise such adherence, build up and delivery of liquid droplets from the nozzle outlet.

Disclosure of Invention

The present invention provides a nozzle for delivering a liquid/gas mixture, comprising:

- 5 a body having a flow through passage leading to an outlet;
an expansion zone proximate the outlet, and at least one
discontinuity in the expansion zone, said discontinuity being adapted to
reduce liquid film adherence at the outlet.

Preferably, each discontinuity is substantially of circumferential extent.

- 10 Preferably, the or each discontinuity is a step-wise enlargement of the expansion zone.

The expansion zone preferably has a plurality of step-wise enlargements.

- 15 Preferably, the flow passage also has a restriction or compression zone spaced upstream from the expansion zone. The restriction or compression zone is preferably a smoothly converging portion of the flow passage, and which leads to a throat portion which is intermediate the restriction zone and the expansion zone.

- 20 The flow passage is preferably generally circular in cross-section with the restriction and expansion zones being generally conical.

- The or each step-wise enlargement in the expansion zone is/are preferably in the form of a circumferential edge having a first diameter, a radially outwardly extending surface which is generally normal to the central axis of the flow passage, and an axially extending cylindrical surface
25 having a second diameter which is a predetermined amount larger than the first diameter, and which leads to the next adjacent step-wise enlargement or the outlet.

- In one specific embodiment, the intermediate throat portion has a diameter of about 4mm, the axial cylindrical surface of a first step-wise
30 enlargement has a diameter of about 5mm, and the axial cylindrical surface of second and third step-wise enlargements have diameters of about 6mm and 7mm respectively. The restriction zone preferably converges from a diameter of about 10mm to the 4mm diameter of the throat portion over an axial distance of about 5mm. Further, the throat portion preferably extends
35 about 13mm, the cylindrical surfaces of first and second step-wise enlargements extend about 3mm in the axial direction, and the cylindrical

surface of a third step-wise enlargement extends about 4mm in the axial direction.

5 A particularly preferred embodiment is formed by a plurality of axially aligned nozzles in accord with the present invention wherein the outlet of one nozzle is adapted to deliver a liquid/gas mixture to a mixed nozzle and wherein adjacent nozzles are separated by gas and/or liquid inspiration zones such that inspired gas and/or liquid is adapted to mix with the liquid/gas mixture as it passes from the outlet of the one nozzle to the inlet of the next adjacent axially aligned nozzle.

10 The number of nozzle stages separated by inspiration zones can be varied as desired.

In use with embodiments in accord with the disclosure in AU-A-51454/93 I have found that in the environment of internal combustion engines a minimum quantity of pressurised air is required to atomise a liquid fuel to a desired particle size. In one prototype this has been established at less than 1% stoichiometric air at 100 psi. That pressurised air is forced through an injector to shear droplets from the conical sheet of fuel with the resultant fuel/air mixture exiting via a delivery nozzle in accord with an embodiment of the present invention.

20 The addition of premix air which is a minimum quantity of air necessary (when combined with primary air which effects a shearing action of the fuel within the injector body) that facilitates a preparation of a high quality premix for good combustion. The quantity of premix air including atomising air is normally approximately 5% of the total required for a stoichiometric mixture.

25 With the further addition of vaporisation air (tertiary air) it is possible to vaporise the fuel and give further premix to enhance combustion. A vaporisation air use understood to mean the minimum quantity of air necessary (when combined with primary and secondary air) to vaporise the fuel and give further premix to enhance combustion. Such tertiary air can be inspired into the fuel/air mixture by means of a further novel stage or via radially disposed air inlets on a shroud extending past the outlet of the second nozzle stage. Of course, as stated above, the number of nozzle stages can be varied as desired.

35 I have found that a single or multiple nozzle arrangement in accord with the present invention not only ameliorates fuel film adherence but also

creates good mixing and reduces the velocity of and broadens the fuel air mixture allowing entry of further air into the mixture.

A secondary air nozzle can be attached to an inlet manifold of internal combustion engine or used to entrain other fuels or both fuel and air.

When used in the environment of a pressurised injector of the form disclosed in AU-A-51454/93 the efficiency of a nozzle of the present invention is not dependent on a negative pressure generated by an engine which can be the case for, say, air-assisted injectors.

Brief Description of Drawings

Preferred forms of the present invention will now be described by way of example with reference to the accompanying drawings, in which:

Fig. 1 is a schematic longitudinal sectional view of an embodiment of a nozzle in accord with the present invention;

Fig. 2 is a schematic longitudinal section view of the nozzle of Fig. 1 and a part of a known liquid/gas mixing apparatus;

Fig. 3 is a schematic detailed view of a portion of the nozzle of Fig. 1 showing the flow of gas/liquid mixture and action of the gas stream on liquid which has adhered to the surface of the expansion zone;

Fig. 4 is a general arrangement sectional view of an embodiment of an injector mounted to an embodiment of a two stage nozzle arrangement of the present invention;

Fig. 5 is a magnified view of a portion of the injector of Fig. 4;

Fig. 6 schematically depicts an injector nozzle arrangement of Fig. 4 configured to provide direct injection into an inlet manifold of an internal combustion engine;

Fig. 7 is a sectional view of the injector and nozzle arrangement of Fig. 4 mounted on an intake manifold; and

Fig. 8 is a view similar to Fig. 7 but showing the injector and nozzle arrangement mounted on an intake manifold in an alternative to that of Fig. 7.

Best Mode

The drawings show an elongate nozzle 10 with a centrally extending through passage 11, a restriction or compression zone 12 at an inlet end 13 and an expansion zone 14 proximate an outlet 15.

The expansion zone 14 is in the form of a series of three step-wise enlargements 16 each of which define circumferential discontinuities along the flow passage 11. Each step-wise enlargement 16 has a circumferential edge 17, a radially outwardly extending surface 18 which is generally normal to the central axis of the nozzle 10, and an axially extending cylindrical surface 19 having a diameter which is a predetermined amount larger than that of its associated edge 17.

The restriction zone 12 has a conical surface 20 which converges to the diameter of a throat portion 21 which is intermediate the restriction zone 12 and the expansion zone 13.

Referring to Figure 2, which shows the nozzle 10 mounted in a part 30 of a liquid/gas mixing apparatus which is generally as disclosed in AU-A-51454/93 to the present application. The mixing apparatus includes a liquid valve 31 which intermittently delivers a radially or conically outwardly projecting sheet of liquid into an annular flow passage 32. The mixing apparatus 30 has gas valving (not shown) which delivers a gas stream through the passage 32 at least from a time just prior to the liquid valve 31 being opened and at least to a time just after the liquid valve 31 is closed. The stream of gas through the passage 32 acts to shear liquid particles away from the sheet of liquid producing a fine mist of liquid particles entrained in the stream of gas.

The liquid/gas mixture flows through the passage 32 of the mixing apparatus 30. The passage 32 communicates with the flow passage 11 of the nozzle 10 which is positioned downstream of the point at which the liquid particles are sheared away from the liquid sheet. The nozzle 10 defines the outlet for the mixing apparatus 30 for delivering the liquid/gas mixture which may be a fuel/air mixture into the combustion chamber of an internal combustion engine (not shown).

In use, the liquid/gas mixture enters the nozzle 10 and is compressed through the restriction zone 12 before passing into the intermediate throat portion 21. This serves to accelerate the stream of gas and liquid particles. When the stream reaches the expansion zone 13, the liquid/gas mixture expands as it passes each of the edges 17 and is thereafter delivered through the outlet 15.

When liquid droplets that have adhered to the flow passage reach the first edge 17, it is believed that the action of the gas stream passing over the

discontinuity causes the accumulated liquid to be drawn off from the surface as relatively small particles, that is, having a particle size which is considerably smaller than if the accumulated liquid had been allowed to discharge from the nozzle expansion zone without such discontinuities.

5 More particularly, the discontinuities defined by the step-wise enlargements 16 cause the stream of gas (with entrained liquid droplets) to flow and expand radially outwardly over and around the edges 17 producing turbulence adjacent the radially projecting surface 18.

10 It has been observed that the nozzle 10 of the embodiment of Figs. 1-3 removes adhered liquid from the expansion zone before it is delivered through the outlet 15 as undesirably large liquid droplets which are generally not able to be burnt efficiently in a normal combustion cycle. This benefit is achieved whether the liquid valve 31 and gas valve (not shown) of the mixing apparatus 30 are opened/closed intermittently to
15 produce intermittent bursts of liquid/gas mixture, or are kept open so as to deliver a continuous stream of the liquid/gas mixture.

In the general arrangement view of the embodiment of Fig. 4 there is shown an injector and nozzle combination 40 comprising a solenoid actuated injector 41 fitted with a two stage nozzle arrangement 42.

20 Injector 41 comprises a solenoid cover 42 which houses a solenoid slug 43 and shuttle retainer 44.

Solenoid control needle 45 is housed within needle guide 46 which is disposed within injector body 47. Needle seat 48 is interposed between needle 45 and atomiser nozzle 49 which directs liquid/gas mixture into air
25 mixing nozzle 50. Between atomiser nozzle 49 and air mixing nozzle 50 there are disposed a plurality of radially extending inspiration passageways 51 while about shroud 52 there are disposed a plurality of tertiary air inspiration passages 53 downstream from the outlet of air mixing nozzle 50.

In the embodiment of Fig. 4 it has been found that of the order of 1%
30 stoichiometric air at 100 psi coupled to air inlet 54 has been sufficient to shear fuel droplets from a conical sheet of fuel, which fuel is fed via fuel inlet 55.

To better appreciate the functioning of the airflow and needle movement reference should be made to Fig. 5 which depicts circumferential
35 gap 56 between needle 45 and the bore within injector body 41 to permit the passage of high pressure gas past a conical spray of liquid which forms upon

movement of needle 45 away from seat 48. After liquid has been sheared from the conical sheet it passes along passage 56 then through a plurality of circularly disposed passageways 57 which feed into atomiser nozzle 49 then through the secondary air inspiration zone defined by passages 51 before entering air mixing nozzle 50.

Referring to Fig. 6 which shows an injector and nozzle arrangement of Fig. 4 mounted above an inlet manifold venturi 60.

Another potential installation arrangement is shown in Fig. 7 where the embodiment of Fig. 4 is mounted to a naturally aspirated or supercharged air inlet manifold 70 with an air bleed passageway 71 feeding inlet manifold air to provide secondary air between nozzles 49 and 50.

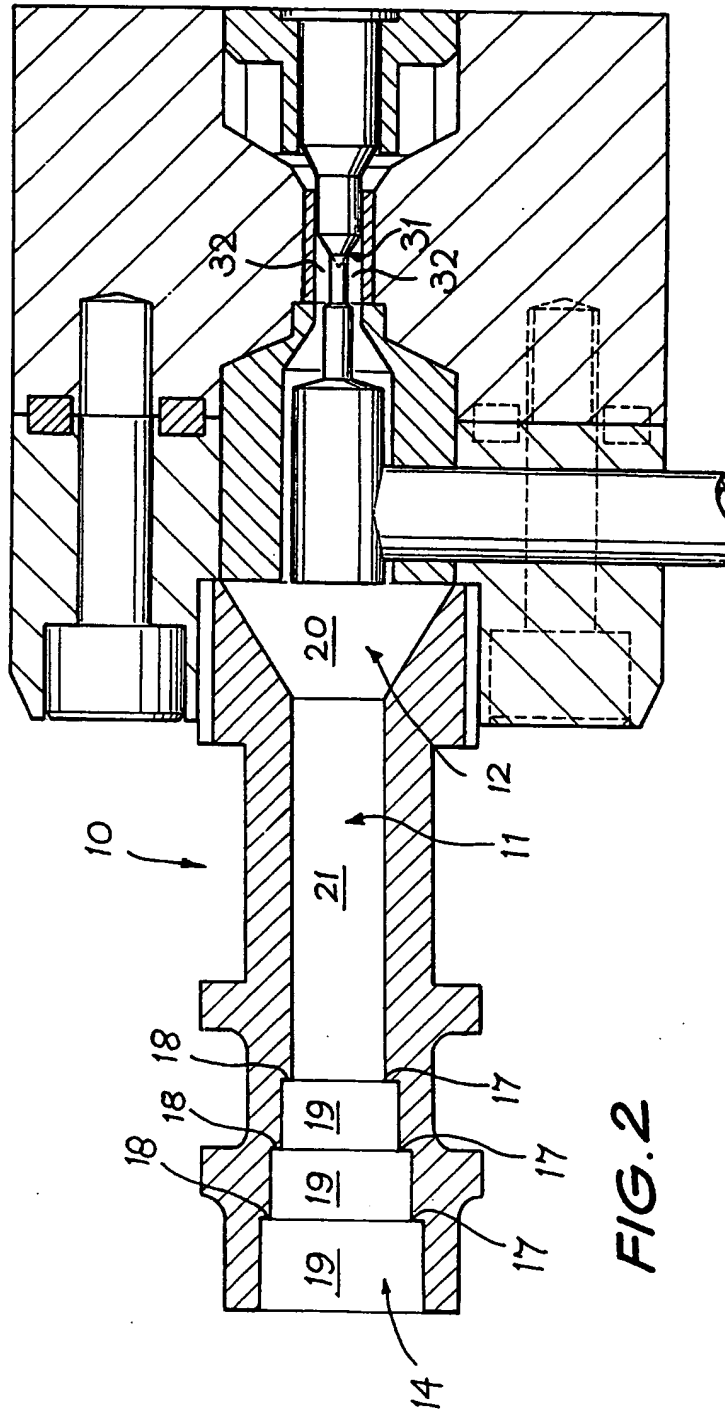
Fig. 8 shows yet another mounting arrangement for a naturally aspirated or supercharged air inlet manifold 80 where the injector body 41 is mounted to manifold 80 with manifold air directly feeding into passages 51 rather than by a bypass arrangement as in Fig. 7.

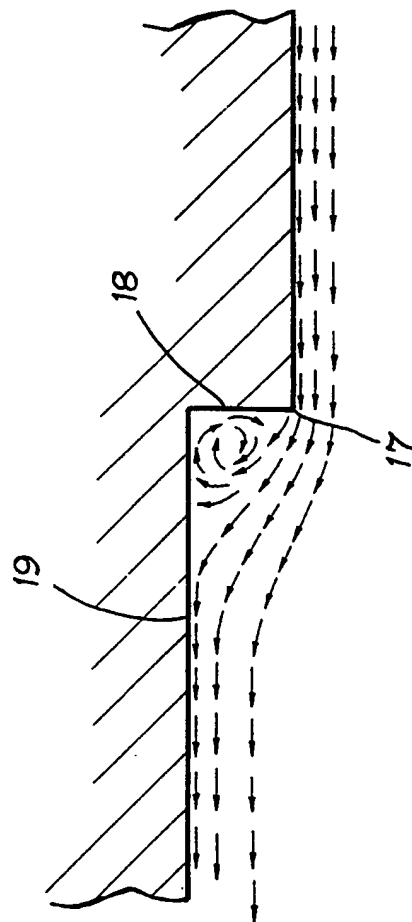
While the nozzles of the depicted embodiments have been described in conjunction with mixing apparatus, it will be appreciated that each nozzle may be used in single or multi-stage form in any application where a liquid/gas mixture is to be delivered subject to any relevant design criteria.

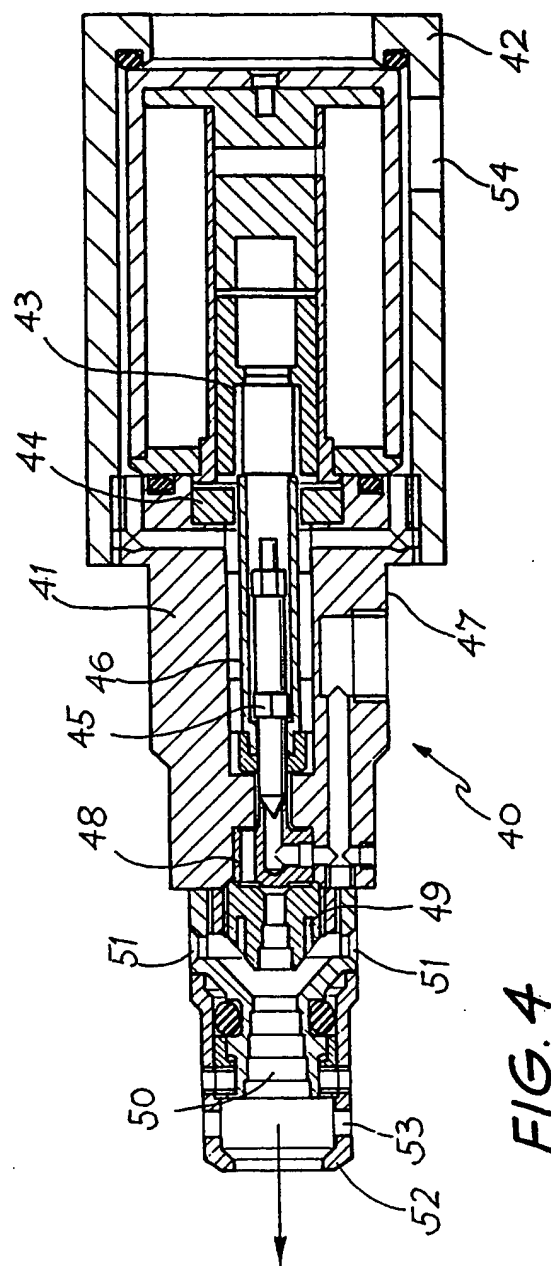
It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

CLAIMS:

1. A nozzle for delivering a liquid/gas mixture, comprising:
a body having a flow through passage leading to an outlet;
an expansion zone proximate the outlet, and at least one
5 discontinuity in the expansion zone, said discontinuity being adapted to
reduce liquid film adherence at the outlet.
2. A nozzle as claimed in claim 1 wherein the at least one discontinuity
is substantially of circumferential extent.
3. A nozzle as claimed in claim 1 or 2 wherein the at least one
10 discontinuity is a step-wise enlargement of the expansion zone.
4. A nozzle as claimed in claim 3 wherein there are a plurality of
discontinuities.
5. A nozzle as claimed in any one of the preceding claims wherein the
flow through passage has a restriction zone upstream from the expansion
15 zone.
6. A nozzle a claimed in claim 5 wherein the restriction zone is a
smoothly contracting portion of the flow passage which leads to a throat
portion between the restriction and expansion zone.
7. A nozzle as claimed in any one of the preceding claims wherein the
20 flow through passage is of a generally circular cross-sectional shape.
8. A nozzle arrangement for delivering a liquid/gas mixture comprising
a plurality of nozzles as claimed in any one of claims 1-4 wherein the
nozzles are axially aligned and spaced apart by gas and/or liquid inspiration
zones.
- 25 9. A nozzle arrangement as claimed in claim 8 or any one of claims 1-4
wherein the outlet of the nozzle arrangement is surrounded by a downstream
extending shroud, and wherein said shroud comprises inspiration zones for
gases and/or liquids to be added to the liquid/gas mixture downstream of the
outlet.







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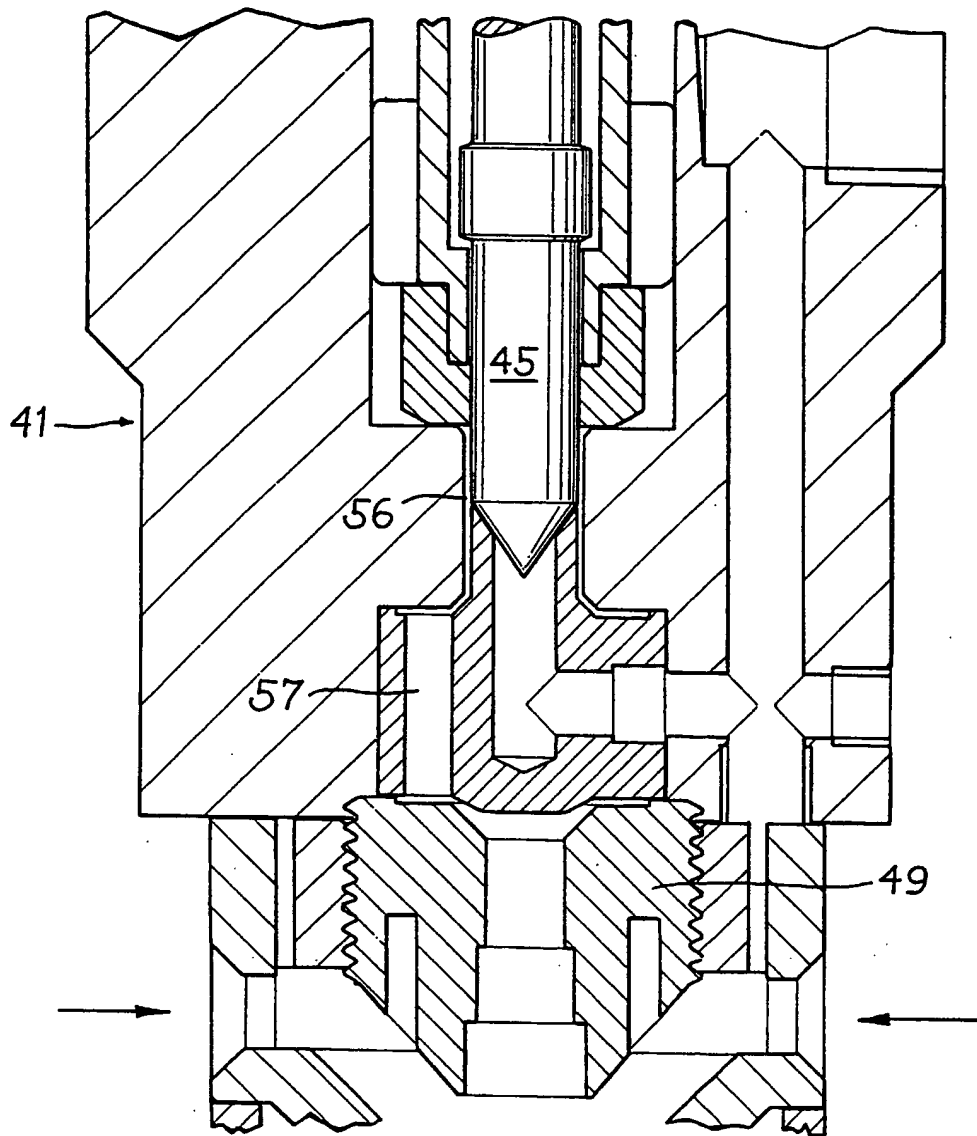


FIG. 5

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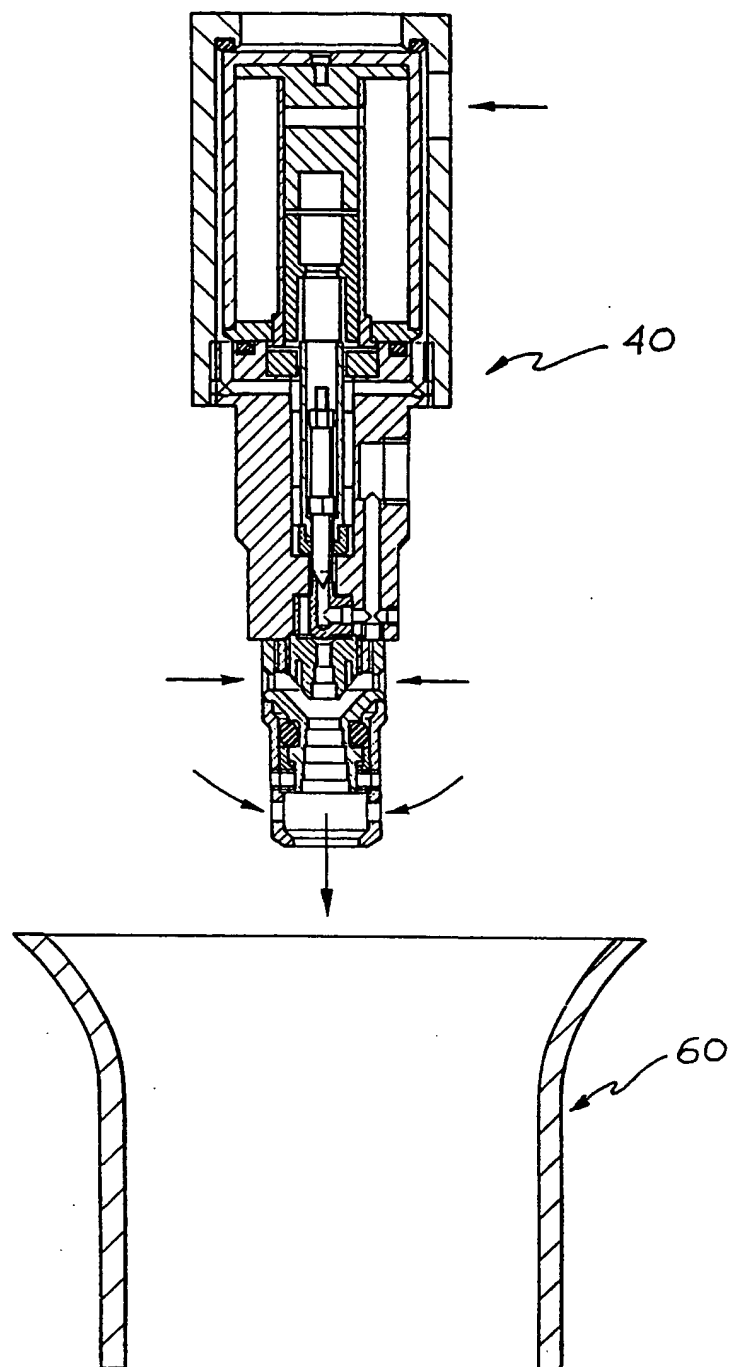


FIG. 6

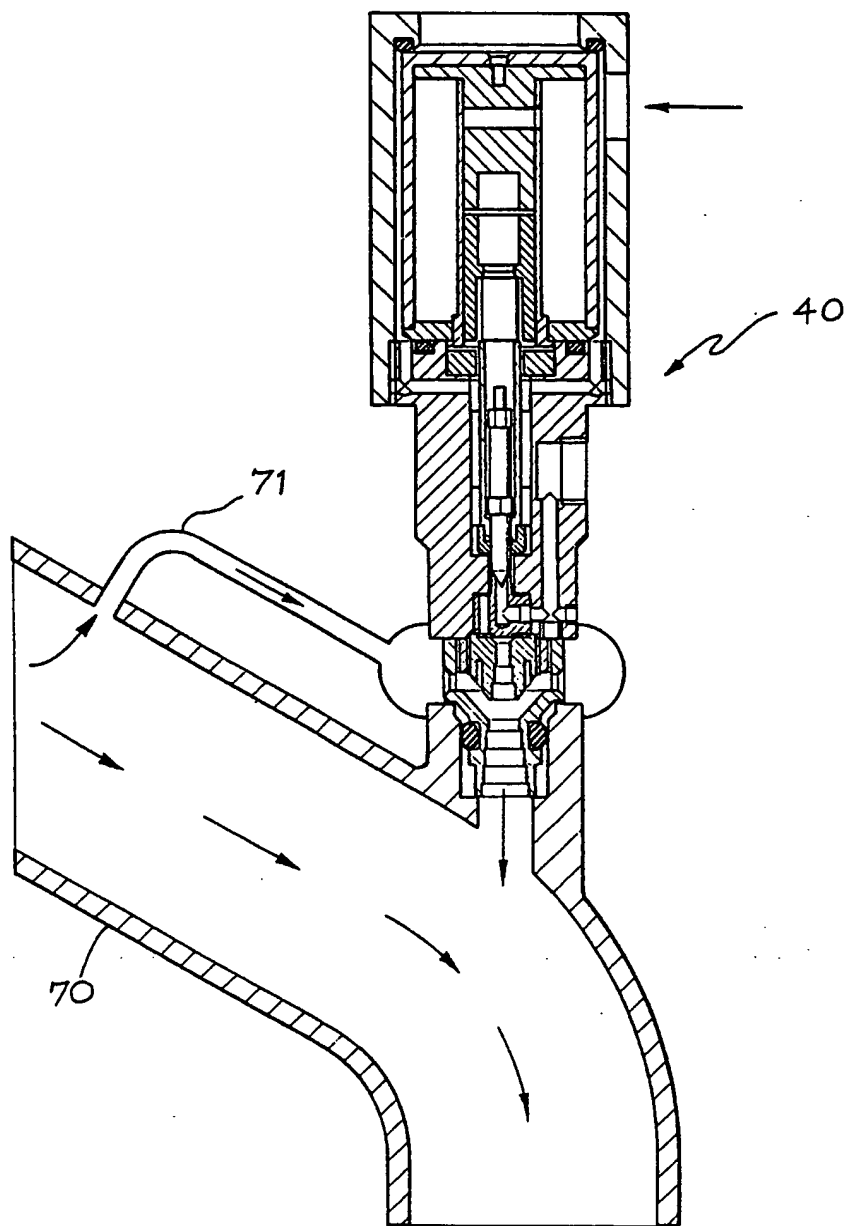


FIG. 7

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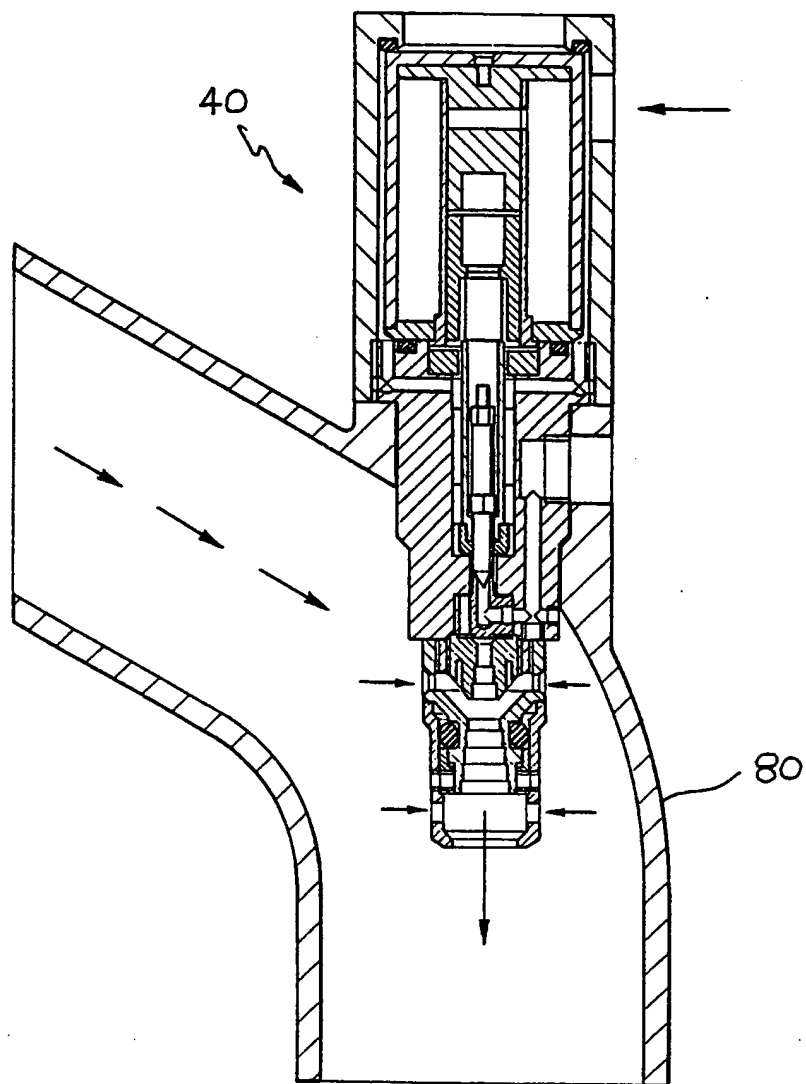


FIG. 8

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 96/00346

A. CLASSIFICATION OF SUBJECT MATTER		
Int Cl ⁶ : B05B 1/26, F02M 61/18, F15D 1/08, 1/06		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) IPC : B05B 1/26, F02M 61/18, F15D 1/08, 1/06		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched AU : IPC as above		
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C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Patent Abstracts of Japan, JP 7-12030 A (MITSUBISHI ELECTRIC CORP) 17 January 1995 Abstract; drawing	1-5
X Y	WO 95/04881 A (FORD MOTOR COMPANY) 16 February 1995 Page 5, line 31 - page 6, line 9; claim 1; figures 2-5	1-7 8
Y	US 5294056 A (BUCHHOLZ et al) 15 March 1994 Abstract; column 2 lines 32-66; figure 1	1-8
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C <input checked="" type="checkbox"/> See patent family annex		
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Date of the actual completion of the international search 26 July 1996		Date of mailing of the international search report 12 AUG 1996
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INTERNATIONAL SEARCH REPORT

International Application No.

PCT/AU 96/00346

C (Continuation)

DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2174760 A (PNEUPAC LIMITED) 12 November 1986 Page 1, lines 89-96; page 2, lines 30-54; claims 1-5; figure 3	1-5
X	US 4559275 A (MATT et al) 17 December 1985 Column 1, lines 44-55; figure 5	1, 2, 5-7

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No.
PCT/AU 96/00346

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report				Patent Family Member			
JP	7-12030	DE	4413937	US	5411212		
WO	95/04881	US	5449114				
US	5294056	DE	4130351	JP	5-209574		
GB	2174760	DE	3614872				
US	4559275	CH JP	659864 59-9306	DE	3320753	GB	2123981